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# Design and Implementation of a Framework for Neurological Disorder Detection System Using Speech Analysis Using AI

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**Abstract**
Neurological disorders such as Parkinson's disease and Alzheimer's disease affect speech production and communication abilities. Variations in speech patterns including articulation, rhythm, pitch, vocal intensity, and fluency can act as early indicators of neurological abnormalities. This paper presents a Machine Learning and Deep Learning-based Speech Analysis System for detecting neurological disorders using speech signals. The proposed system performs preprocessing operations such as noise reduction and normalization on speech recordings. Mel Spectrogram feature extraction is applied to represent speech signals in the time-frequency domain. Multiple machine learning algorithms including Decision Tree, Random Forest, Support Vector Machine (SVM), and Long Short-Term Memory (LSTM) are implemented for classification. Among these models, the LSTM model achieved superior performance due to its ability to capture temporal speech dependencies. The system classifies speech samples into Alzheimer's, Parkinson's, and Healthy categories. The implementation is developed using Python, Django Framework, Librosa, TensorFlow/Keras, and Scikit-Learn to provide an interactive web-based platform for automated speech analysis and prediction. Experimental evaluation using Accuracy, Precision, Recall, and F1-Score demonstrates that the proposed system provides reliable and efficient neurological disorder detection.

**Keywords:** Speech Analysis, Neurological Disorder Detection, Mel Spectrogram, LSTM, Parkinson's Disease, Alzheimer's Disease, Machine Learning, Deep Learning.

## I. Introduction

The rapid advancement of artificial intelligence and speech signal processing technologies has created new opportunities for healthcare applications, especially in the early detection of neurological disorders. Diseases such as Parkinson's disease and Alzheimer's disease significantly affect speech production mechanisms and cause noticeable variations in vocal patterns. Changes in articulation, rhythm, pronunciation, pitch, and speaking fluency often appear during the early stages of neurological disorders.

Traditional diagnostic methods rely on neurological examinations, clinical observation, brain imaging, and cognitive assessments. Although these approaches are effective, they are expensive, time-consuming, and require medical experts. Therefore, speech analysis has emerged as a non-invasive and cost-effective alternative for neurological disorder detection.

The proposed system titled "Neurological Disorder Detection System using Speech Analysis using AI" analyzes speech recordings using machine learning and deep learning techniques. Speech signals are processed and transformed into Mel Spectrogram representations to extract meaningful features. Machine learning algorithms such as Decision Tree, Random Forest, SVM, and LSTM are implemented for classification. Among these algorithms, LSTM provides better prediction accuracy because of its ability to analyze sequential speech patterns.

The developed system is implemented using Python with Librosa for speech processing, TensorFlow/Keras for deep learning, Scikit-Learn for machine learning, and Django for web deployment. The system enables users to upload speech recordings and obtain automated prediction results for neurological disorders.

## II. Related Work

Several studies have explored machine learning and deep learning techniques for speech-based neurological disorder detection.

Several researchers have explored machine learning and deep learning techniques for neurological disorder detection using speech analysis. Max Little and colleagues demonstrated that Support Vector Machine (SVM) models achieve high accuracy in detecting Parkinson's disease using dysphonia measurements. Carlos Orozco-Arroyave proposed multimodal speech analysis using acoustic and linguistic features for Parkinson's disease identification. Deep learning approaches such as LSTM and CNN models were later introduced for detecting speech abnormalities and pathological speech patterns from spectrogram representations.

Researchers also applied advanced neural network techniques for Alzheimer's disease detection through spontaneous speech analysis and audio-visual learning frameworks, showing improved classification performance. Recent studies focused on multimodal deep learning combining speech and gait analysis, Explainable AI for identifying significant speech frequency bands, and multilingual speech classification using Mel-frequency features. Furthermore, federated learning techniques were proposed to ensure privacy-preserving neurological speech analysis while maintaining model efficiency and scalability.

These studies collectively demonstrate that speech analysis combined with machine learning and deep learning techniques provides effective solutions for early neurological disorder detection.

## III. Existing System

Existing neurological disorder detection systems primarily depend on clinical examinations, neurological testing, and manual speech observation. Medical experts analyze patient symptoms, cognitive abilities, and speech behavior to diagnose neurological disorders.

Some systems utilize basic signal processing and machine learning approaches to identify speech abnormalities. However, these methods have several limitations because they cannot effectively analyze complex temporal speech patterns and often fail to identify early-stage neurological conditions.

Drawbacks of Existing System

1. Expensive diagnostic procedures.

2. Dependence on medical experts and specialists.
3. Time-consuming diagnostic process.
4. Difficulty in early-stage detection.
5. Lack of automated speech analysis systems.
6. Limited accuracy in detecting complex speech abnormalities.

## IV. Proposed Methodology

The proposed system automatically detects neurological disorders by analyzing speech signals using machine learning and deep learning techniques.

Initially, speech recordings are collected from Alzheimer's patients, Parkinson's patients, and healthy individuals. The speech signals undergo preprocessing operations such as noise removal and normalization to improve signal quality.

After preprocessing, Mel Spectrogram feature extraction is applied to convert speech signals into time-frequency representations. These extracted features capture important speech characteristics such as frequency variations, vocal energy distribution, and temporal speech patterns.

The processed features are used to train multiple machine learning algorithms including Decision Tree, Random Forest, Support Vector Machine (SVM), and Long Short-Term Memory (LSTM). Among these algorithms, the LSTM model achieves superior performance due to its ability to capture sequential dependencies in speech signals.

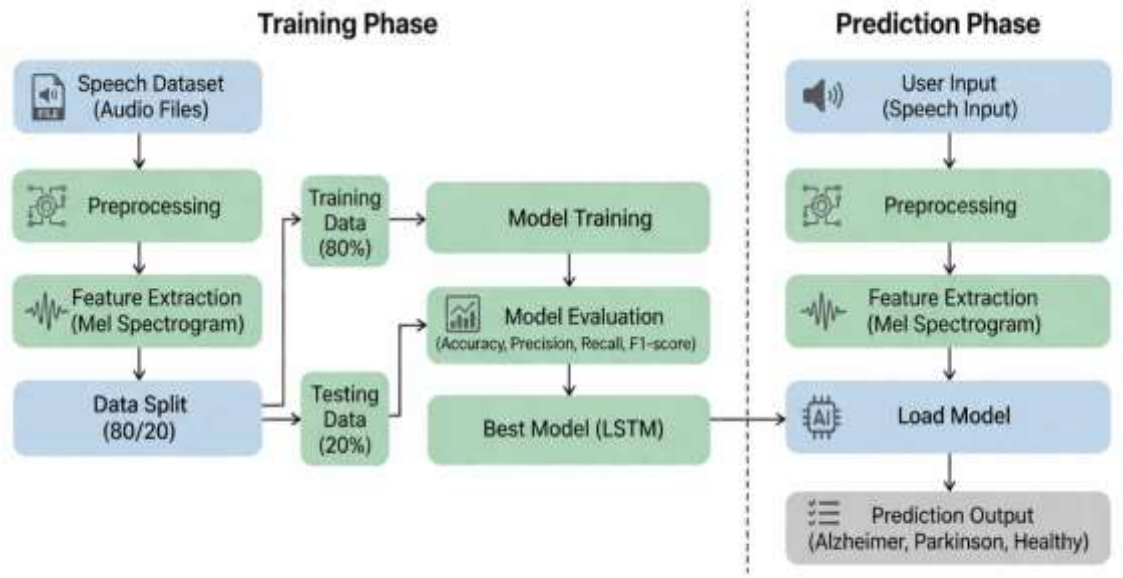
The trained model is integrated into a web-based application developed using Python and Django Framework. Users can upload speech audio files through the application interface, and the system predicts whether the speech belongs to Alzheimer's, Parkinson's, or Healthy categories.

The proposed approach provides an automated, non-invasive, and efficient solution for neurological disorder detection.

## V. System Architecture

The system architecture consists of the following layers:

- **Dataset Layer** – Stores speech recordings for training and testing.
- **Preprocessing Layer** – Performs speech normalization and noise reduction.
- **Feature Extraction Layer** – Extracts Mel Spectrogram features from speech signals.
- **Machine Learning Layer** – Implements Decision Tree, Random Forest, SVM, and LSTM models.
- **Model Storage Layer** – Stores trained models and preprocessing objects.
- **User Interface Layer** – Provides audio upload and prediction display.
- **Backend Layer (Django)** – Handles communication between frontend and machine learning modules.
- **Database Layer** – Stores user details and prediction history.
- **Prediction Layer** – Performs real-time speech classification and result generation.




## VI. Implementation

The Neurological Disorder Detection System is implemented using Python and advanced speech signal processing techniques. Librosa is used for loading audio files and extracting Mel Spectrogram features. Machine learning algorithms such as Decision Tree, Random Forest, and SVM are implemented using Scikit-Learn, while the LSTM deep learning model is implemented using TensorFlow/Keras.

The dataset consists of 149 speech samples categorized into Alzheimer's, Parkinson's, and Healthy classes. Approximately 80% of the data is used for training, while 20% is used for testing.

Speech signals are converted into Mel Spectrogram representations using Short-Time Fourier Transform (STFT) and Mel Filter Banks. The extracted features are normalized using StandardScaler before model training.

The LSTM model architecture includes an LSTM layer, Dropout layer, Dense layer, and Softmax output layer for multi-class classification. The trained model is integrated into a Django web application that enables users to upload speech recordings and receive prediction results.

The trained models and preprocessing objects are stored using Joblib and HDF5 formats for efficient deployment and prediction.

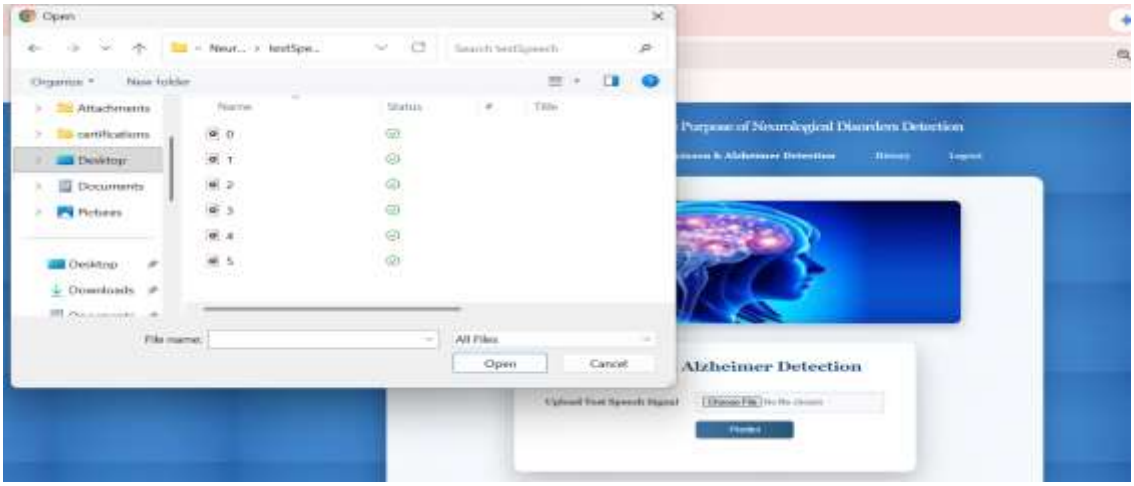
## VII. Results and Discussion

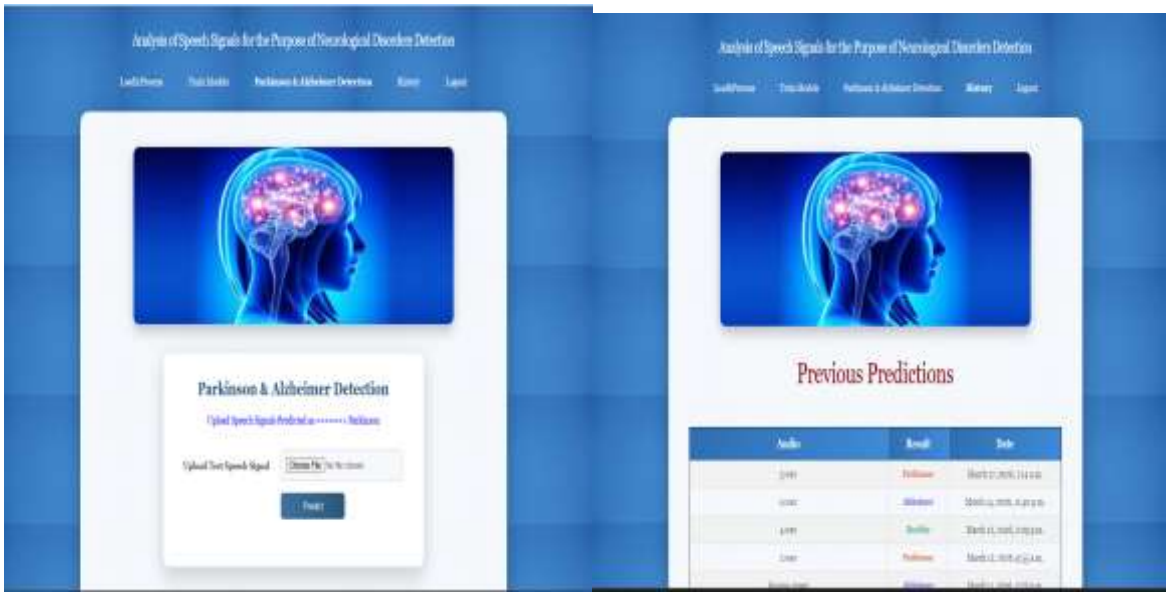
The proposed Speech-Based Neurological Disorder Detection System was evaluated using Decision Tree, Random Forest, Support Vector Machine (SVM), and Long Short-Term Memory (LSTM) models.

Experimental results demonstrated that the LSTM model achieved the highest classification performance compared to other machine learning algorithms. The model effectively captured temporal speech characteristics and identified speech abnormalities associated with neurological disorders.

Performance metrics such as Accuracy, Precision, Recall, and F1-Score were used to evaluate the system. The results confirmed that Mel Spectrogram features combined with LSTM provide reliable classification performance for detecting Alzheimer's disease and Parkinson's disease.

The developed web application successfully analyzed uploaded speech recordings and generated prediction results in real-time. The system provides a reliable and non-invasive solution for automated neurological disorder detection.





## VIII. Conclusion

The Speech-Based Neurological Disorder Detection System using Artificial Intelligence was developed to assist in identifying neurological disorders through speech analysis. The system uses speech

preprocessing techniques and Mel Spectrogram feature extraction to analyze speech signals and identify abnormalities.

Machine learning algorithms such as Decision Tree, Random Forest, SVM, and LSTM are implemented for classification, with LSTM achieving superior performance due to its ability to process sequential speech data.

The developed web-based system enables users to upload speech recordings and obtain automated prediction results for Alzheimer's disease, Parkinson's disease, or healthy speech patterns.

Experimental results demonstrate that the proposed approach improves classification accuracy and provides a cost-effective, non-invasive, and efficient solution for neurological disorder detection. The system can support researchers and healthcare professionals in early-stage diagnosis and monitoring of neurological conditions.

## IX. Future Work

The proposed system can be further enhanced by integrating larger and more diverse speech datasets to improve model generalization and prediction accuracy.

Advanced deep learning architectures such as CNN-LSTM hybrid models and Transformer-based speech analysis models can be implemented to improve speech classification performance.

Future enhancements may include:

- Real-time speech monitoring and prediction.
- Mobile application integration for remote healthcare support.
- Multilingual speech analysis capabilities.
- Explainable AI techniques for improving model transparency.
- Integration with healthcare systems and cloud-based platforms.
- Federated learning approaches for privacy-preserving speech analysis.

These enhancements can improve the scalability, accessibility, and reliability of the neurological disorder detection system.

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